Proceedings of the Seventeenth (2007) International Offshore and Polar Engineering Conference
Lisbon, Portugal, July 1-6, 2007

ISBN 978-1-880653-68-5; ISBN 1-880653-68-0(Set); ISSN 1098-6189 (Set)

Implementation of an Anistropic Hardening Constitutive Model for Large Deformation Analysis

Seboong Oh, Taegyung Kim
Dept. of Civil Engineering, Yeungnam Univ.
Gyeongsan, Gyeongbuk, Korea

Ohkyun Kwon
Dept. of Civil Engineering, Keimyung Univ.
Daegu, Korea

Jong-Seok Lim
Dept. of Civil Engineering, Mokpo National Univ.
Mokpo, Korea

ABSTRACT.

For the analysis of embankments on soft clays, a constitutive equation was proposed, which is based on an anisotropic hardening rule and the total stress concept. The constitutive model was implemented in ABAQUS code, such that large deformation analysis can be performed accurately and efficiently. The formulation includes (1) finite strain plasticity on the basis of the Jaumann stress rate, (2) implicit stress integration and (3) consistent tangent moduli. A large deformation analysis was performed with the proposed constitutive model using ABAQUS. In the analysis of an actual embankment, it was found that the proposed model is formulated accurately and efficiently. The proposed model could predict the undrained behavior of soils reasonably.

KEY WORDS: Constitutive model; anisotropic hardening; embankments; finite strain

INTRODUCTION

Anisotropic hardening models, in the context of elasto-plasticity, can capture successfully the actual behavior of soils (Dafalias, 1981; Mroz et al., 1981; Borja and Amies, 1994). The anisotropic hardening description tried to model hysterisis and cyclic nonlinearity but it is also useful in simulating general nonlinearity under an overconsolidated or K_0 condition (Dafalias, 1981; Lee and Oh, 1995).

An elasto-plastic constitutive model, based on an anisotropic hardening rule and the total stress concept, was proposed to model the stress-strain behavior from small to large strains (Oh et al., 2000). The main idea of the model concerns an anisotropic hardening description according to the generalization of the isotropic hardening rule.

It is necessary to numerically integrate the constitutive equation for implementing to a nonlinear analysis code. The implicit integration method is regarded as the most accurate scheme, while the tangential stress-strain modulus should be consistent with the linearization in order to conserve the quadratic rate of convergence. (Ortiz and Popov, 1985; Simo and Taylor, 1985; Dodds, 1987; Crisfield, 1991; Oh and Lee 2001).

In nonlinear continuum mechanics, hypoelasticity is frequently used, but limited to its applicability to small stretching and the isotropy of elasticity (Hughes, 1984). However an objective rate, the Jaumann stress rate is commonly used in the study of geomaterials. In this study, the implicit stress integration of an anistropic hardening constitutive model is formulated under hypoelasticity, based on the Jaumann stress rate for large deformation analysis. Tangent modulus is also formulated, consistent with the stress integration procedure, and coded into a user subroutine of general-purpose finite element program, ABAQUS (HK & S, 2001). The proposed model is applied to an embankment on soft clays as an example.

FINITE DEFORMATION PLASTICITY

For finite deformation plasticity, the constitutive equation based on hypoelasticity can be written as follows (Hughes, 1984; Lush, 1990):

$$\overset{\nabla}{\mathbf{T}} = \mathbf{C}^e : \left(\mathbf{D} - \mathbf{D}^p\right) \tag{1}$$

where

$\overset{\nabla}{\mathbf{T}} \equiv \dot{\mathbf{T}} - \mathbf{WT} + \mathbf{TW}$	Jaumann rate of Cauchy stress $\mathbf{T}$
$\dot{\mathbf{T}}$	material time derivative of $\mathbf{T}$
$\mathbf{C}^e = 2G\mathbf{I} + (K - \frac{2}{3}G)\mathbf{1}\otimes\mathbf{1}$	isotropic elasticity tensor
K, G	elastic bulk and shear moduli